Fingerprint Sample Quality Metric NFIQ 2.0

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Abstract: At the NIST March 2010 workshop on "The Future of NFIQ", the development of a new (open source) version of NFIQ in consultation and collaboration with users and industry was recommended. Following this recommendation, NIST and BSI set up a joint project for the development of a successor version of NFIQ. This paper explains the reasons and needs for the development and details the planned approach and development process.

1 Introduction and timeline

Quality measurement plays a vital role in improving biometric system accuracy and efficiency during the capture process (as a control-loop variable to initiate reacquisition), in database maintenance (sample update), in enterprise-wide quality assurance surveying, and in invocation of quality-directed processing of samples in multimodal systems. If quality can be improved, either by sensor design, by user interface design, or by standards compliance, better performance can be realized. For those aspects of quality that cannot be designed-in, an ability to analyze the quality of a live sample is needed.

Biometric quality analysis is a technical challenge because it is most helpful when the quality measures reflect the performance sensitivities of one or more target biometric comparison subsystems. NIST addressed this problem in August 2004 when it issued NIST Fingerprint Image Quality (NFIQ) algorithm. NFIQ is a fingerprint quality measurement tool; it is implemented as open-source software; and is used today in very large government both in U.S. and worldwide, and commercial deployments. NFIQ's key innovation is to produce a quality value from a fingerprint image that is directly predictive of expected recognition performance. NFIQ serves as a publicly available reference implementation. With advances in fingerprint technology since 2004, an update to NFIQ is needed.

At the NIST March 2010 workshop on "The Future of NFIQ", workshop participants overwhelmingly recommended the development of a new (open source) version of NFIQ in consultation and collaboration with users and industry.

In February 2011, NIST and BSI issued a Call for Participation (CfP), inviting research organizations and industry members to support development of NFIQ 2.0. Specifically, NIST and BSI requested

- Submission of matchers whose comparison scores will be used for training of NFIQ 2.0 (by May 2, 2011),

- Suggestions and technical contributions towards composition and computation of NFIQ 2.0 features (by August 29, 2011),

- Fingerprint images demonstrating NFIQ 1.0 anomalies (by September 30, 2011).

In parallel, internal developments at NIST and BSI started with the preparation of interface specifications, database selection and feature examination.

2 Proposed approach for development of NFIQ 2.0

2.1 NFIQ 2.0

We propose development of a set of standardized finger image quality components plus multivariate statistics techniques to relate biometric performance metrics such as false non-match to the standardized quality components (i.e. features). The outcome will be an open source quality assessment algorithm for finger image. Same as NFIQ 1.0, the new NFIQ 2.0 will have two major computation steps:

- Feature extraction, and

- Training of a machine-learning algorithm.

2.2 Feature Extraction

Feature extraction consists of measuring appropriate image characteristics that convey information for comparison algorithms. The feature set may be comprised of elements such as local noise, continuity of ridge flow, area of the finger image impression, and number of minutiae. A feature vector is computed from each image and its components are combined using a trained machine-learning algorithm so that the image quality score is reflective of positive or negative contribution of the sample to the overall performance of the system. Part 4 of ISO/IEC 29794 [ISO-29794-4] defines defect factors for finger images and recommends features and characteristics of finger images at both local and global structures that are related to performance of fingerprint recognition systems. Additionally parts 2 [ISO-19794-2] and 4 [ISO-19794-4] of ISO/IEC 19794 Biometric data format standard define features such as zonal quality or minutiae quality.

In collaboration with industry, a set of quality components will be defined and perhaps formally standardized. These quality components shall model failure modes and sensitivities of current fingerprint recognition algorithms. Examples include: zonal quality, clarity of ridges, size of fingerprint, or number of minutiae. Technical comments and contributions towards the formation and computation of features are requested.

NIST and BSI will develop open-source reference implementations for standardized quality components.

2.3 Training a machine leaning algorithm

Training looks for structure in the data and ultimately building a model to relate the response variable (e.g. performance as false non-match rate, or area-under-ROC-curve) to the exploratory variables (i.e. features or quality components). We explore different multivariate statistical techniques to obtain the optimal model. Training could be customized to a comparison algorithm or generalized to a class of comparison algorithms. NIST and BSI will train a machine-learning algorithm to predict performance of a particular comparison algorithm (i.e. customized NFIQ 2.0) or a general class of comparison algorithms (generalized NFIQ 2.0).

For customized NFIQ 2.0, the training parameters on the machine-learning algorithm will be returned to the provider of the biometric comparison subsystem (matcher) used for training.

The outcome will be a family of quality algorithms that could be application-independent or tuned to particular applications. Interoperability is achieved by uniform interpretation of quality scores; therefore, it expands a marketplace of interoperable products.

2.4 Generalized vs. Customized

NFIQ has been designed to be agnostic to biometric comparison algorithms. For applications where the comparison algorithm is not known a priori or subject to change, a generalized (i.e. biometric comparison independent) image quality assessment algorithm (IQAA) is needed. However, when the comparison algorithm is known, use of an IQAA that is tuned to predict the performance of the deployed comparison algorithm is more suitable. Therefore the next generation of finger image quality, should provide both options of “generalized” (i.e. comparison algorithm-independent) or “customized” (i.e. comparison algorithm dependent).

2.5 Calibration

Interoperability of quality scores is another challenge in exchange of quality scores. Part 1 of the multipart ISO/IEC 29794 Biometric sample quality standard [ISO-29794-1] defines a binary record structure for the storage of a sample’s quality data. It establishes requirements on the syntax and semantic content of the structure. Specifically, it states that the purpose of assigning a quality score to a biometric sample shall be to indicate the expected utility of that sample in an automated comparison environment. That is, a quality algorithm should produce quality scores that target application-specific performance variables. For verification, the default metric would usually be false-non-match rates that are likely to be realized when the sample is verified. This, by itself, is not sufficient for accurate interpretation of quality scores generated by different quality assessment algorithms and therefore some normalization or calibration is needed.

3 Software development framework

As a part of the proposed approach, a software development framework has been specified and developed as a flexible test bed for different feature vectors and machine learning algorithms.

The framework is designed to serve as a layer between modules and applications that use the framework and the available modules. Figure 1 shows a schematic representation of the framework design. It consists of four module interfaces and is used for the development of the NFIQ 2.0 and the final implementation of the algorithm as well. Furthermore, it allows for easy implementation of several versions of the NFIQ 2.0.

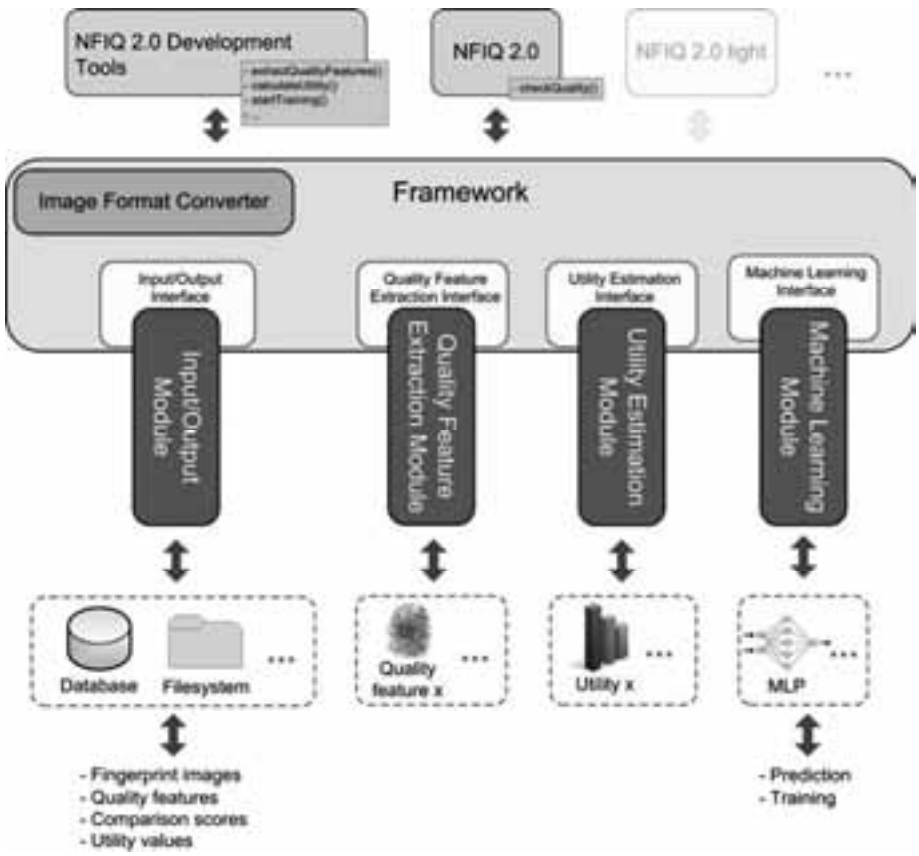

Figure 1: Software development framework design

4 Current Status

The project has seen broad participation from the side of the biometrics industry. All major biometric algorithm providers are active in the development of NFIQ 2.0 and submitted a current version of the SDK for training.

At the time of writing, the software development framework is available for internal testing and a first set of candidate features (using NFIQ 1 features and features proposed in [ISO-29794-4]) has been proposed and preliminarily evaluated.

First detailed results will be available and presented at the NIST IBPC conference in March 2012.

Bibliography

[ISO-19794-2] ISO/IEC 19794-2:2005 “Information technology – Biometric data interchange formats – Part 2: Finger minutiae data”.

[ISO-19794-4] ISO/IEC 19794-4:2005 “Information technology – Biometric data interchange formats – Part 4: Finger image data”.

[ISO-29794-1] ISO/IEC 29794-1:2009 “Information technology – Biometric sample quality – Part 1: Framework”.

[ISO-29794-4] ISO/IEC 29794-1:2010 “Information technology – Biometric sample quality – Part 4: Finger image data”.